Study reveals how distinctive termite mounds are ventilated, could offer lessons to human architects

September 2 2015

A soldier termite (Macrotermitinae) in the Okavango Delta. Credit: Wikipedia

As animal architects go, the average termite doesn't have many tools at their disposal - just their bodies, soil and saliva. And as guidance, variations in wind speed and direction and daily fluctuations in temperature as the sun rises and sets.

Despite such limitations, the tiny insects have managed build structures that are efficiently ventilated - a challenge that human architects still struggle with.

Led by L. Mahadevan, Lola England de Valpine Professor of Applied Mathematics, of Organismic and Evolutionary Biology, and of Physics, a team of researchers that included Hunter King, a post-doctoral fellow and Samuel Ocko, a graduate student, both in the Mahadevan lab, has for the first time has described in detail how termite mounds are ventilated. The study reveals that the structures act akin to a lung, inhaling and exhaling once a day as they are heated and cooled. The study is described in an August 31 paper in the *Proceedings of the National Academy of Sciences*.

"The direct measurements essentially overthrow the conventional wisdom of the field," Mahadevan said. "The classic theory was that if you have wind blowing over the mounds, that changes the pressure, and can lead to suction of CO2 from the interior...but that was never directly measured. We measured wind velocity and direction inside the mounds at different locations. We measured temperature, CO2 concentrations...and found that temperature oscillations associated with day and night can be used to drive ventilation in a manner not dissimilar to a lung. So the mound 'breathes' once a day, so to speak."

Mahadevan first encountered termite mounds more than five years ago, during a visit to the National Center for Biological Sciences in India, and was surprised to learn that many of the ideas about how the mounds functioned hadn't been rigorously tested.

Working with Scott Turner, an Associate Professor at SUNY College of Environmental Science and Forestry, and author of a book that examines animal-built structures, Mahadevan, King and Ocko put together a plan to set out to find more definitive answers.

"It occurred to us that the internal flow profiles predicted by different potential mechanisms qualitatively disagree with each other," King said. "By measuring them directly, we could easily identify the right one. The hard part was figuring out how to sensitively measure these small flows in a confined space defended by glue-and-mud-excreting termites."

Using a series of custom-designed probes, King and Ocko spent several weeks in India, conducting a variety of tests on both live and dead mounds, including taking temperature readings during the day and at night, covering mounds with tarps, blowing air over them and even using vacuum cleaners to test suction.

"After months of hard thought and preparation, it all comes down to hiking through the woods at 4am with a laptop, a lantern, custom-built electronics, and a hole saw," Ocko said. "The 'aha' moment made it all worth it. "

The mechanism they identified relies, in large measure, on the structure of the mounds themselves.

The mounds are built around a large central "chimneys," which reach from gallery - the underground vault where the bulk of the colony lives - to the top of the mound. While the interior of the mound features larger, structural walls, the exterior is far thinner, with wall that, while impermeable to wind, do allow for the exchange of gases.

During the day, Mahadevan explained, as sunlight either directly or indirectly warms the mound's outer walls, the air inside warms, causing it to rise.

"What you get is a convection cell," Mahadevan explained. "The warm air can't move through the walls quickly enough, but it has to go somewhere, and the only possibility is for it to go down into the interior through the central chimney. At night, as the exterior cools, the airflow reverses, and it pulls the air up from the central part of the mound."

The end result, Mahadevan said, is that while CO2 concentrations during the day can reach up to four or five percent in the center of the mound, the airflow at night pulls the gas to the exterior walls, where it can escape by diffusing through the wall. "But what's remarkable here is how the termites are using transients. The temperature outside the mound is oscillating, and they have developed a method to harness that to ventilate their mounds." Mahadevan said.

While the study reveals for the first time how termite mounds truly work, it may also offer lessons human architects could benefit from. "In a large building like the one we're sitting in we have windows and doors that allow us a certain amount of seclusion and privacy, but that also means you have a harder time pushing air around from one part of the building to another,"

While the notion of designing buildings that can be more efficiently ventilated is not new, the principles described in the study might offer new ways to think about such passive ventilation systems.

"Could you drive large scale flows through a building like this one by cleverly opening and closing doors and windows ?" Mahadevan asked. "Rather than spending a great deal of energy for a fan and air conditioning in every room, with the end result being that some people are too hot and some people are too cold... perhaps we should think of the entire thing as a system and these new measurements suggest that if the architecture is appropriate, ventilation can occur by using environmental transients—something for us to think about."

More information: Termite mounds harness diurnal temperature oscillations for ventilation, Hunter King, DOI: 10.1073/pnas.1423242112

Provided by Harvard University